Human Exploration Architectures and Perspectives

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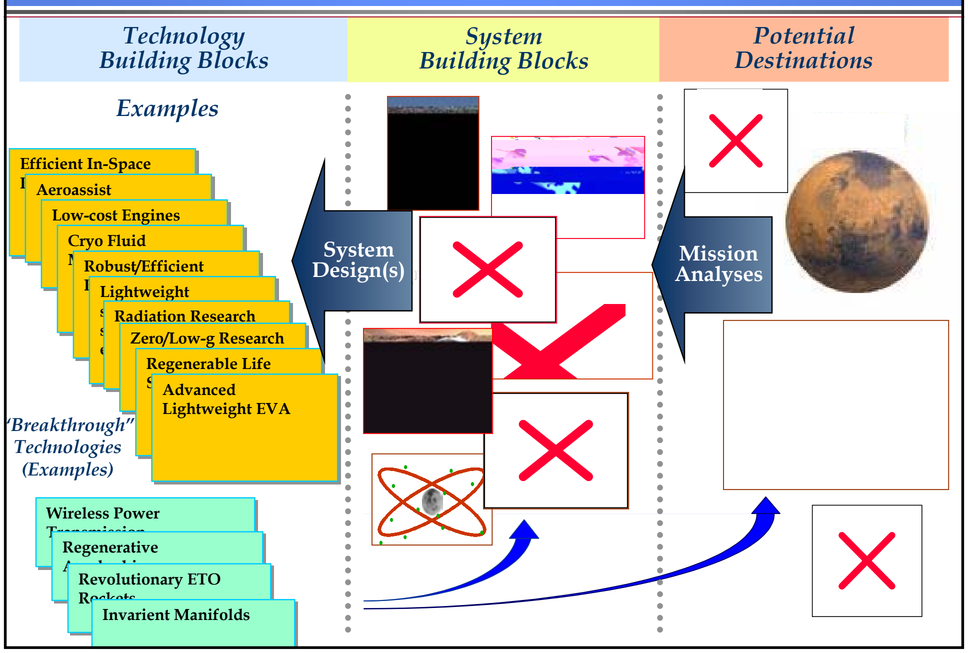
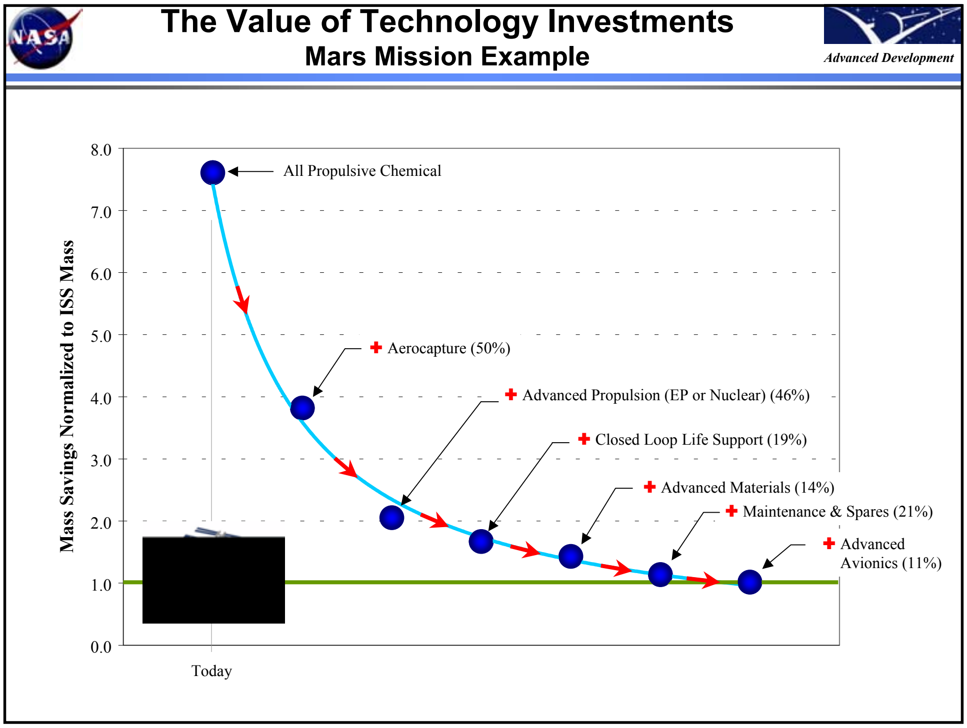
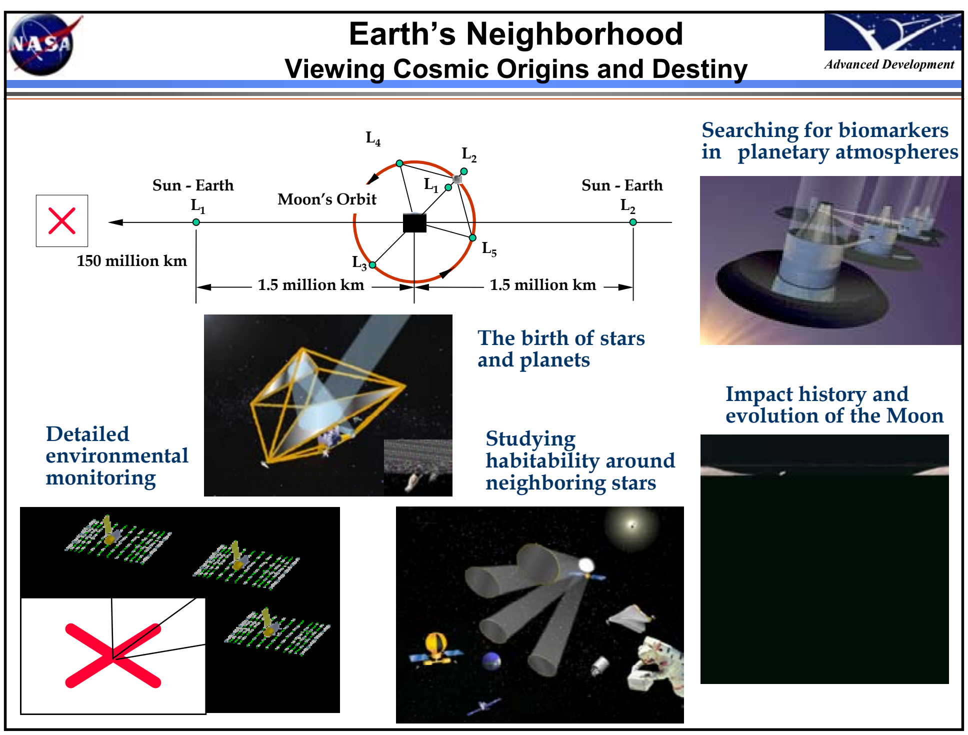
NEXT
Core Capabilities & Technologies

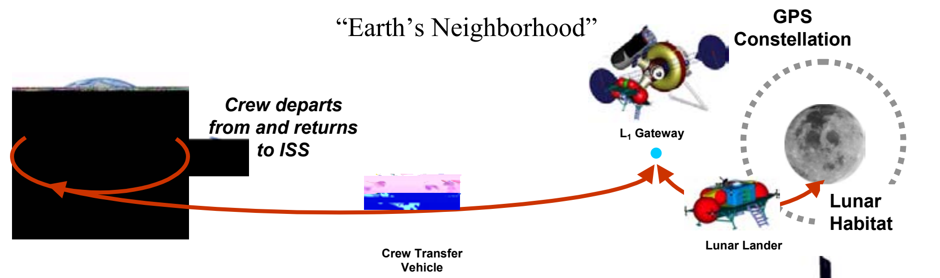



The Value of Technology Investments
Mars Mission Example
Advanced Development
All Propulsive Chemical
✚ Aerocapture (50%)
✚ Advanced Propulsion (EP or Nuclear) (46%)
✚ Closed Loop Life Support (19%)
✚ Advanced Materials (14%)
✚ Maintenance & Spares (21%)
✚ Advanced Avionics (11%)
Mass Savings Normalized to ISS Mass
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Today


Earth's Neighborhood
Viewing Cosmic Origins and Destiny
Advanced Development
Sun - Earth L_1
Moon's Orbit
L_4
L_2
L_1
L_3
L_5
Sun - Earth L_2
150 million km
1.5 million km
1.5 million km
Searching for biomarkers in planetary atmospheres
The birth of stars and planets
Impact history and evolution of the Moon
Detailed environmental monitoring
Studying habitability around neighboring stars

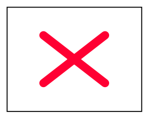
Gateway Architecture

Advanced Development



Crew Transfer Vehicle

- Transports crew between ISS and Gateway
- Nominal aerocapture to ISS, or direct Earth return contingency capability



L_1 Gateway

- "Gateway" to the Lunar surface
- Outpost for staging missions to Moon, Mars and telescope construction
- Crew safe haven

Lunar Lander

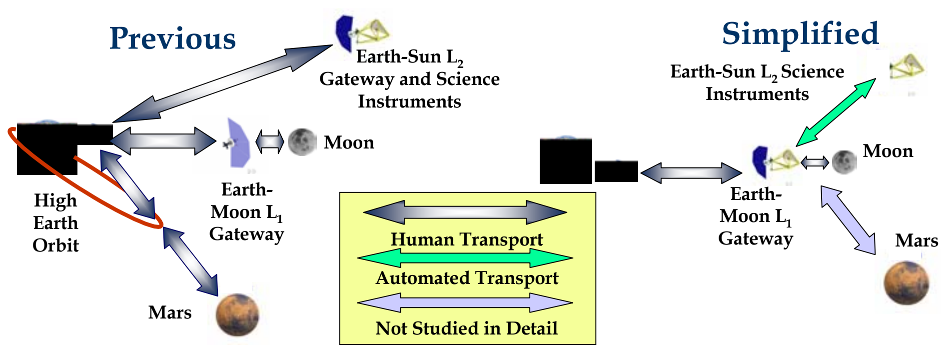
- Transports crew between Gateway and Lunar Surface
- 9 day mission (3 days on Lunar surface)

Lunar Habitat

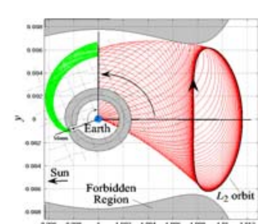
- 30-day surface habitat placed at Lunar South Pole
- Enables extended-duration surface exploration and ops studies

Simplifying Earth's Neighborhood Infrastructure

Advanced Development



- Discovered new approach for meeting trajectory requirements for vehicles in Earth's Neighborhood with new benefits;
  - **–Low energy transfers between Lunar L1 and solar L2**
  - **–Created efficient Gateway Concept**



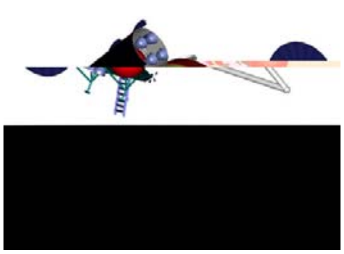
Servicing Halo Missions from

Gateway Configurations

Advanced Development

Launch Configuration

LEO, Transit, L1 Stand-by Configuration



Lunar Operations Configuration

Telescope Operations Configuration

Lunar L_1 "Gateway"

Advanced Development

Key Attributes

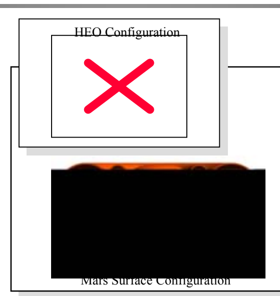
- Crew of 4
- Global lunar access – 3 day
- Lunar polar outpost – 30 days
- Earth-Sun Telescope servicing
- ISS staging platform
- Missions serve as "stepping stones" by providing an opportunity to test technology and operational concepts, reducing risk of future exploration endeavors
- Architecture can be bought "by the yard" resulting in increasing capabilities and operational experience
- Employs modest augmentation of commercial launch vehicles
- Common architecture elements for all Earth's Neighborhood missions

Mars Mission Vehicle Concepts

Advanced Development

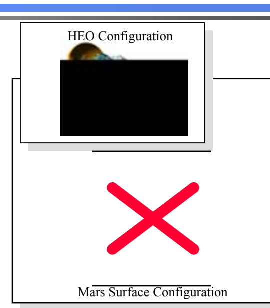
Mars Transit Vehicle

- Supports mission crew of six for up to 200-day transits to and from Mars
- Return propulsion stage integrated with transit system
- Provides return-to Earth abort capability for up to 30 hours post-TMI
- Total Vehicle Mass in High-Earth Orbit = 188 mt



Mars Surface Habitat

- Vehicle supports mission crew of six for up to 18 months on the surface of Mars
- Provides robust exploration and science capabilities
- Descent vehicle capable of landing 36,000 kg
- Total Vehicle Mass in High-Earth Orbit = 99 mt



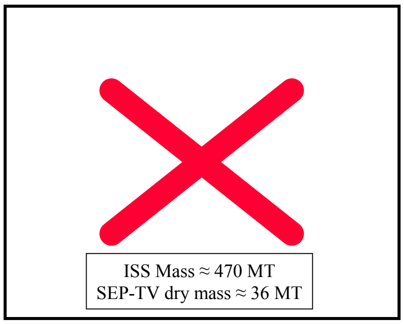
Descent/Ascent Vehicle

- Transports six crew from Mars orbit to the surface and back to orbit
- Provides contingency abort-to-orbit capability
- Supports six crew for 30-days
- Vehicle capable of utilizing locally produced propellants
- Total Vehicle Mass in High-Earth Orbit = 103 mt

Solar Electric Propulsion Concept

Advanced Development

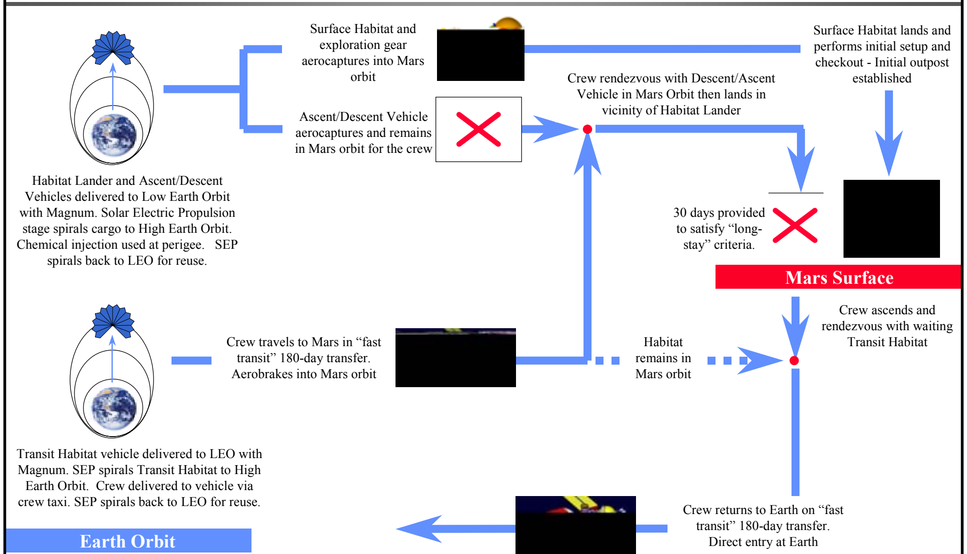
- Array sized to provide 1700 kW_e throughout first mission
- 14700 m^2 $CuInS_2$ array area
- 171 m span (wingtip-wingtip)
- 17 x 100 kW_e Hall Thruster Propulsion
- Articulated boom thruster



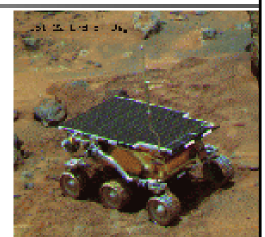
ISS Mass ≈ 470 MT
SEP-TV dry mass ≈ 36 MT

Mars Mission Overview

Advanced Development

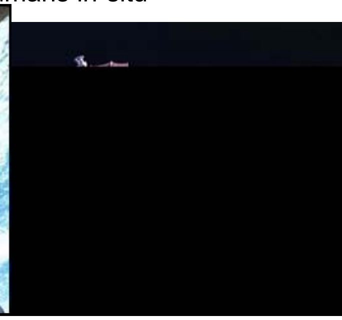


Human and Robotics History



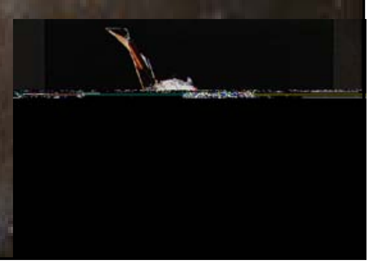
- Humans and robots collaborate in every mission
  - Differences in missions characterized by the interface and proximity

Hubble Space Telescope and Apollo demonstrated significant increase in rate of science return through direct interaction of humans in-situ



Human and Robotics History

- Robots and machines augment capabilities of humans and extend their reach into the solar system and beyond
  - Remote observations and measurements
  - Interaction with the environment
  - Demonstration and implementation of technologies



What are the Often Stated Questions?

Advanced Development

Humans vs. Robots?

- Humans are essential in the use of robots
  - Issue of proximity
  - Degree of control, autonomy, interaction
- Relative Performance -

  Robotic Missions
  - Robots can be deployed in hazardous environments before committing humans
  - Robotic missions are smaller bite-sized missions with smaller funding commitments
  - Because they are smaller scale missions, science and its rate of return is limited. May take decades to obtain desired science (Mars)

  Human Missions
  - Scale of missions inherently larger/ more costly
  - More complete range of observations/measurements possible on a mission
  - In-situ investigations and human interaction closer to what is possible in the laboratory
  - Ability to intercede in hardware/software problems and failures
  - Greater flexibility to react to the totally unexpected and changing objectives
- The question is partially institutional- Human Space Flight vs. Space Science missions

What are the Often Stated Questions?

Advanced Development

Humans and robots using the best capabilities of each?

- As before, we already try to do this in current robotic and human missions
- The usual progression in this discussion- humans and robots working together in-situ (planetary surface example)
  - Leads to visions of awkward relationships between people debilitated by their space suits and current designs for remotely operated robots
  - Without significant advancements, potentially leads to humans and robots less capable together than if they went their own ways
- With current views of capabilities, possibilities have been described as-
  - Tele-operated robots with humans in close proximity
  - Semi-autonomous robots scout for humans- rovers/ airborne reconnaissance
  - Robots explore the most hazardous terrain for safety purposes
  - Humans go EVA for detailed examination of prepared sites, scout for additional robot exploration
  - Robot assistants tag along to help out and reduce burdens of EVA
  - These roles and interactions can all be valid

Characteristics (partial list)

Humans

- Complex thought processes
- Lifetime of experiences and learned knowledge is accessed instantaneously for immediate response to rapidly changing situations
- Complex computer / motor capabilities
  - Learned motor skills not requiring conscious thought
    - eye-hand coordination
    - balance- walking and talking/ chewing gum
- Abstract prediction loosely based on experience
- Decision making based on other than facts (loyalty, humor, emotion, desires, fear for survival, etc.)
- Acute skills of observation and interpretation
- Imagination, strategic thinking, ability to set or change priorities
- Intuitive problem solving

Characteristics (partial list)

Machines

- Programmed, logical response
- Increasing automated reasoning
- Parallel processing
- Designed in strength- can easily surpass / augment human strength
- Detailed, accurate, massive computation capabilities
- Precise, quantifiable measurements
- Exactly repetitive computational and mechanical actions
- Stored coordinates for exact locations
- Mechanical capabilities- fluid control, filtering, power generation; other system functions

Character of Current Operations

Advanced Development

Human missions

- Teams of people on the ground to assist astronauts
  - Monitor systems, oversee mission objectives and progress, mission decisions
  - Up link and communicate instructions and commands for normal operation of spacecraft, systems and experiments
  - Work with flight crews to solve onboard problems
  - Provide training
- Significant workload for astronauts to maintain complex systems and spacecraft
- Extra Vehicular Activity
  - People debilitated by suits
  - Reduced mobility, dexterity, strength
  - Injuries to hands from gloves
  - Kept alive and allow external work to be done using brains and motor skills

Character of Current Operations

Advanced Development

Robotic Spacecraft

- Team of people on the ground
  - Monitor systems, oversee mission objectives and progress, mission decisions
  - Up link commands for normal operation of spacecraft, systems and experiments
  - Mars surface example; As much as 40 minutes for round trip communication
    - Send commands for next operation
    - Receive latest onboard information and response to commands
    - Analyze next move
    - Send next set of commands

Observations

Advanced Development

- For both human and robotic missions, more autonomy in machines/robots are needed to reduce the necessary degree of human interaction
  - Emerging computer-machine intelligence and problem solving capability
  - More complete and accessible onboard information
  - Reduce ground support / save money
- More productive questions might be:
  - **How do we apply the best state of technology to get the most from our machine, robot, computational, and human capabilities?**
  - **How do we develop the most effective interfaces between people and machines**
  - **Ultimately, how do we augment/ integrate human performance with machines to maximize overall mission performance, flexibility, and achievement?**

Addressing the Interaction Between Humans and Machines

Advanced Development

- Characterize and model the human being as a complete system of computational ability, sensors and effectors
  - Sensors- touch, sight, hearing, taste, total body system of feel, pain, temperature sensors
- Develop and <u>apply</u> technologies to maximize machine autonomy and physical capability
- Define mission functions in detail
- Identify an integrated human/machine capability that can be employed to maximize performance of the functions
  - Develop the most effective interfaces, considering all possibilities

This should culminate in:

Augmentation of humans through complete integration with advanced machines, combining capabilities to to achieve mission performance levels that far surpass the best performance of each.

An Example, Putting this to Work-
EVA Example

Advanced Development

Objective- Astronaut is more capable than he is w/o EVA equipment- Achieve maximum mission performance

- Protected in a suit:
  - Mechanical or inflatable pressure?
  - Light weight systems- materials, nano/mems
  - Built in advanced thermal, radiation protection
  - Outer skin sloughs or peels off to remove dust
- Full computational capability
  - Interaction w/o keyboards: Voice, direct brain communication?
  - HUD, video to retina?
  - All possible mission data, CAD views, etc. readily accessible
- Augmented sensors, strength/dexterity
  - Synthetic muscles, actuators incorporated in suit
  - Full, augmented sensory input
  - multi-spectral enhanced vision
  - Built in inflatable splints for injured limbs
  - Ability to medicate
- Communication of experiences, data and discoveries
  - Example: Retinal sensors- People on earth share discoveries through the astronauts' eyes- ability to instantly recall what was seen